Rapport de mission effectuée

à Bordeaux

(1er au 5 juillet 2013)

9ème conférence du groupe de travail OILB

'Integrated Protection of Stored Products'(IOBC/WPRS)

P. Silvie

CIRAD, UPR SCA (102)

Remerciements

Je remercie toutes les personnes qui ont rendu possible ma participation à cette intéressante réunion, 9ème conférence du groupe de travail de l'Organisation Internationale de Lutte Biologique (OILB) section Ouest Paléarctique (SROP), et en particulier, le Directeur de l'UPR 102 (Systèmes de culture annuels), Florent Maraux, et l'animateur de notre équipe 'Carabe', François-Régis Goebel.

Résumé (base de données Agritrop du CIRAD)

Ce n'est pas un hasard si l'INRA de Bordeaux (Mycsa) a été l'organisateur de cet évènement. Le Dr. Francis Fleurat-Lessart, éminent spécialiste de la question de la protection des denrées stockées, tenait certainement à apporter, avant son départ, sa contribution au groupe de travail de l'Organisation Internationale de Lutte Biologique (OILB, ou IOBC, Section 'West Paleartic') intitulé 'Integrated Protection of Stored Products' (IPSP). Les réunions de ce groupe de travail ont lieu tous les 2 ans et depuis 2005, la participation de pays non-européens est une constante. Cette 9ème réunion a ainsi regroupé 94 participants provenant de 26 pays dont l'Allemagne, l'Espagne, l'Italie, la France, la Grèce, le Portugal, le Royaume-Uni, la Slovénie mais également le Brésil, le Canada, les Etats-Unis d'Amérique, l'Inde, Israël, la Russie, la Suisse (Agroscope), la Turquie, et du côté du continent africain, l'Algérie, l'Angola, le Cameroun, bien représenté, le Bénin (modestement, à travers ma participation en appui aux travaux de A. Togola, de AfricaRice). D'autres participants étaient annoncés (de Corée, d'Irak, du Nigeria, du Pakistan, de Tunisie, du Venezuela) mais n'ont pas pu venir.

Les 46 exposés oraux, accompagnés de la présentation effective de 21 affiches scientifiques (sur les 40 abstracts diffusés) ont concerné les 6 thématiques suivantes (en anglais):

- recent advances in IPSP and current trends in post-harvest IPM;

- stored product pests and pathogens biology and ecology in relation with detection, traceability, inspection and legislation in the post-harvest food chain;

- utilization of phytochemicals and semiochemicals in stored product IPM;

- non-chemical control of pests and pathogens at the post-harvest stages (physical, biological, bio-technical, etc.);

- chemical control in stored-product IPM (fumigation, alternative chemicals);

- IPSP strategies: decision support tools and integrated approach in practice (3 exposés seulement).

Les modèles biologiques ont été majoritairement les insectes, très peu d'exposés ont présenté des résultats d'expérimentation portant sur la contamination par des champignons, aucun exposé sur les problèmes de rongeurs. Le livre des résumés a été délivré sous la forme d'une clé USB, en plus du support papier, plus pratique pour le suivi de la conférence. Le site https://colloque.inra.fr/iobc-ipsp-2013conference donne toutes les informations nécessaires (liste des participants, programme complet). De nombreux contacts ont été établis (détaillés dans le rapport de mission), notamment avec des chercheurs travaillant sur les huiles essentielles ou extraits de plantes, ou la formulation avec des argiles. Ces contacts seront transmis à nos partenaires du sud, qui pourront, le cas échéant, les activer pour l'élaboration de futurs projets de recherche en réseau (networking).

Introduction : remarques générales

Parmi les 20 groupes de travail de l'Organisation Internationale de Lutte Biologique (OILB, Section 'West Paleartic') celui intitulé 'Integrated Protection of Stored Products' (IPSP) traite des activités présentées en Annexe 1. Il se réunit tous les deux ans. Depuis 2005, la participation de pays non-européens a été admise et encouragée. Cette 9ème réunion a ainsi regroupé près d'une centaine de participants provenant de 26 pays dont l'Allemagne, l'Espagne, l'Italie, la France, la Grèce, le Portugal, le Royaume-Uni, la Slovénie mais également le Brésil, le Canada, les Etats-Unis d'Amérique, l'Inde, Israël, la Russie, la Suisse, la Turquie, et du côté du continent africain, l'Algérie, l'Angola, le Cameroun, bien représenté (4 participants), le Bénin (travaux de A. Togola, AfricaRice). D'autres participants étaient annoncés (abstracts disponibles) mais n'ont pas pu venir, *a priori* (Corée, Irak, Nigeria, Pakistan, Tunisie, Venezuela).

La conférence s'est tenue dans l'Agora du domaine de Haut Carré, un ancien couvent construit entre 1954 et 1957, à l'initiative de la congrégation de la Sainte Famille de Bordeaux. La réunion dans ce cadre architectural dépouillé de type monastère cistercien, s'est déroulée dans une atmosphère calme, pas totalement contemplative, dans une chapelle transformée en auditorium, ornée de vitraux du maître verrier français Gabriel Loire. C'est en 1997 que l'Université de Bordeaux I a racheté ce site qui avait auparavant accueilli l'Ecole Internationale de la Francophonie.

Sur les 49 exposés oraux initialement prévus, trois n'ont pas été réalisés (absence des participants de Grèce, Pakistan et Tunisie). Ces exposés furent accompagnés de la présentation effective de 21 affiches scientifiques (sur les 40 abstracts diffusés) dans le cloître.

Le livre des résumés a été délivré sous la forme d'une clé USB (format pdf), en plus du support papier, plus pratique pour le suivi de la conférence. Le site https://colloque.inra.fr/iobc-ipsp-2013conference donne toutes les informations nécessaires (liste des participants, programme complet).

Les six thématiques abordées lors du meeting

Les thématiques suivantes ont été abordées lors de six sessions:

- recent advances in IPSP and current trends in post-harvest IPM (session 1);

- stored product pests and pathogens biology and ecology in relation with detection, traceability, inspection and legislation in the post-harvest food chain (session 2);

- utilization of phytochemicals and semiochemicals in stored product IPM (session 3);

- non-chemical control of pests and pathogens at the post-harvest stages (physical, biological, bio-technical, etc.) (session 4);

- chemical control in stored-product IPM (fumigation, alternative chemicals) (session 5);

- IPSP strategies: decision support tools and integrated approach in practice (session 6).

La première partie de la session 5 (contrôle chimique) a été organisée la même matinée que la seconde partie de la session 3, ce qui ne m'a pas permis de la suivre. De nombreuses personnes ont suivi cette session 5 (en lien avec l'importance des infrastructures de type 'silo', la problématique de l'interdiction de certains insecticides, et l'usage de la phosphine).

Les modèles biologiques ont concerné majoritairement des insectes, Coléoptères et Lépidoptères. Très peu d'exposés ont présenté des résultats d'expérimentation portant sur la contamination par des champignons, aucun n'a porté sur l'action des rongeurs.

Parmi les Coléoptères, les espèces les plus communes suivantes furent mentionnées : *Sitophilus granarius*, *S. zeamais*, *S. oryzae*, *Tribolium castaneum*, *T. confusum*, *Trogoderma granarium*, *Callosobruchus maculatus*, *C. chinensis*, *Rhyzopertha dominica*, *Acanthoscelides obtectus*, *Oryzaephilus surinamensis, Cryptolestes ferrugineus*, *Lasioderma serricorne*.

A l'inverse, *Prostephanus truncatus* (Bostrichidae), connu comme ravageur important du maïs en Afrique, n'a fait l'objet d'aucune présentation.

Parmi les Lépidoptères, *Plodia interpunctella*, *Sitotroga cerealella, Ephestia elutella, Ephestia kuehniella, E. cautella,* furent les espèces les plus fréquemment citées.

À noter, pour les amateurs de vin, l'existence d'un lépidoptère (*Nemapogon granellus*) dont les chenilles s'attaquent aux bouchons en liège, en Italie.

Les ennemis naturels évoqués dans les abstracts appartiennent aux groupes des insectes parasitoïdes et des champignons entomopathogènes.

Pour ce qui concerne la session 3, le professeur Tapondjou, du Laboratoire de chimie appliquée et environnementale (*University of Dschang, Faculty of Science, Laboratory of Environmental and Applied Chemistry,Box 183, Dschang-Cameroon)* a présenté une très bonne synthèse (**Phytochemicals and semio-chemicals use in IPSP programs**) sur les produits agissant de manière insecticide et fongicide. En voici le résumé :

Abstract: During storage, foods are currently destroyed by insects and other pests. These pests generally carried in their body fungus that can produce mycotoxins which cause risks to humans and animals; thus, the interaction between pest infestation and fungus contamination in stored food has been established. Generally damages caused by pest and fungi are reduced through chemical control, but there is a strong debate about the safety aspects of chemical preservatives since they are considered responsible for many carcinogenic and teratogenic attributes as well as residual toxicity. With the growing interest of the use of either essential oils or plants extracts as alternatives for stored product protection, screening of plant extracts, essential oils and derived components for their insecticidal and anti-fungal properties has become of increasing importance. As the matter of fact, several articles in the literature published plethora of compounds from plant origin exhibiting both insecticidal and fungicidal activities. There is therefore a need of knowledge on phytochemicals and plants that could be used as insecticides and fungicides. Here, we review chemicals of plant origin and species with insecticidal and fungicidal activities. An exhaustive literature search was conducted using scientific databases, chemical databases, botanical databases, and books to identify published papers related to insecticidal and fungicidal chemical compounds stemmed from plant species and it was established that 3 main chemical classes were most cited for these activities: alkaloids, phenolics, and terpenoids. This review presents plant species and some of their chemical constituents of importance exhibiting both insecticidal and fungicidal activities that could be used as alternative for integrated protection of stored products.

L'Annexe 2 présente les divers résumés des exposés ou posters portant sur cette thématique. L'usage d'huiles essentielles semble préféré. L'emploi d'argile (activée) dans une formulation pour pouvoir bénéficier d'un relargage lent des composés des huiles a fait l'objet d'une présentation (Annexe 2, Abstract 30). La terre de diatomées, employée comme agent desséchant, a été mentionnée dans plusieurs exposés, avec le lien entre son efficacité et l'humidité externe (au Nord Cameroun, par exemple, Annexe 2, Abstract 35).

Des thèmes divers ont été abordés au cours des six sessions, avec parfois des exposés uniques (isolés) sur un thème donné, comme les travaux intéressants réalisés en écologie chimique (Annexe 3), ou l'usage de filets imprégnés d'alpha-cyperméthrine 0.34 % w/w contre *Ephestia elutella* ou *Lasioderma serricorne* (Annexe 4, présenté par BASF). Certaines études ont abordé la distribution des insectes dans un magasin, ainsi que celle des aérosols appliqués. Le suivi des insectes adultes par les phéromones disponibles est de plus en plus employé, mais l'usage de seuils (souvent établis sans bases biologiques) ne semble pas fréquent. La confusion sexuelle a été évoquée. L'emploi de piège de type piège à fosse conique (*pitfall trap*) est effectué dans certains cas pour le suivi des populations à la surface des grains stockés. Améliorer les méthodes de suivi pour mieux exploiter les résultats obtenus est une des recommandations émises par Jim Campbell. Une autre recommandation forte est de 'sortir des laboratoires' (seuls 18% des articles publiés dans la revue *Journal of Stored Products Research* traitent de travaux réalisés hors laboratoire). Cet aspect a été abordé par les trois exposés présentés en session 6 avec des enquêtes.

L'emploi de la fumigation a fait porter l'attention vers le calfeutrage des silos, le recyclage de la phosphine ainsi que sa production par des 'générateurs' externes. Des dispositifs de stockage externe sous bâches, en cours d'expérimentation, ont été également montrés. Le traitement de magasins vides est une autre réalité de la protection. Ainsi, des travaux de laboratoire portent sur l'effet de traitements chimiques de diverses surfaces (ciment, céramique, par exemple).

En dehors des problèmes de prévention d'attaque par des insectes, et de conservation de la matière première (grains, farine), la détection de fragments d'éléments contaminants (fragments d'insectes e.g.) dans les produits finis (biscuits, pâtes,..)a fait l'objet de quelques présentations.

Des travaux de nature très fondamentale ont également été exposés (Annexe 5), parfois, dixit certains encadrants, parce que la participation à ce genre de conférence rapprochait les étudiants de la réalité du terrain. Les universitaires sont toujours à la recherche d'applications de leurs travaux dans le 'monde réel'. La conférence a ainsi permis de faire des contacts avec des acteurs de 'mondes' divers.

Contacts établis

De nombreuses personnalités (chercheurs ou autres acteurs) ont pu être rencontrées lors de cette réunion.

Les chercheurs suivants représentent des contacts indiqués pour le montage de futurs projets et la recherche de financements :

- Azefack Tapondjou (Université de Dschang, Cameroun) ;
- Haman Tofel (Université de Ngaoundere, Dép. Sciences biologiques, Cameroun) ;

- Elias Nukenine (Université de Ngaoundere, Dép. Sciences biologiques, Cameroun) ;
- Pascale Chalier (UMR IATE, Université Montpellier II) ;
- Jordi Riudavets (IRTA, Espagne);
- Cornel Adler (Julius Kühn Institut -JKI, Allemagne);
- Matthias Schöller (Biologische Beratung Ltd, Allemagne).

Les trois derniers chercheurs mentionnés sont bien informés sur les projets européens, ou les appels à projets de l'Union africaine. Le thème des denrées stockées a été repris, après 20 ans d'absence (Adler, comm. pers.), par l'ex coopération allemande (GTZ) avec des projets déposés avec le Ghana et le Malawi (réponse attendue pour un projet de conservation en conditions hermétiques).

Les chercheurs suivants représentent des contacts intéressants pour des échanges d'informations sur des méthodes (ou des résultats):

- Ana Magro (Instituto de Investigação Cientifica, Portugal);
- Maria Otilia Carvalho (Biotrop centre/IICT, Portugal);
- Francis Fleurat-Lessart (INRA, UR Mycology and Food Safety- MycSA).

En effet, la coopération du Portugal (chercheuses rencontrées) avec les pays africains (Mozambique, Angola) se fait de manière bilatérale, avec des financements apportés de part et d'autre (Angola, pays riche), sans recherche de réseautage européen.

Les chercheurs suivants représentent des contacts intéressants, au plan de l'excellence scientifique:

- Jana Collatz (Agroscope Reckenholz-Tänikon ART, Suisse) ;
- Lamis Karaki (doctorante labo de Yvan Rahbé, INRA, Lyon);
- A.F. Ndomo (doctorante camerounaise à JKI, Allemagne).

Lors de la conférence, j'ai également pu discuter avec Dr. Catherine Régnault-Roger, Prof. émérite de l'Université de Pau et des pays de l'Adour- UPPA depuis juin 2013, également membre du HCB, membre titulaire de l'Académie d'Agriculture, vice présidente de la CBST, administratrice de l'AFPP, éditrice, membre du comité de rédaction de la revue *Phytoma*, et membre du Comité d'édition de Elsevier (*Industrial products*).

Enfin, deux jeunes agronomes (dont un formé en entomologie, à Tours) ont été rencontrés, Maud Mathie (entreprise en cours de création) et Yann Ciesla (Sitona AgroExpert). Ils proposent leurs services – qu'ils jugent complémentaires - d'expertise, conseil et formation sur la conservation des grains, la fumigation notamment (Yann).

Une revue pour publier : Journal of Stored Products Research

Les conseillers scientifiques au Comité d'édition de la revue dédiée *Journal of Stored Products Research* étaient nombreux lors de la conférence. C'est ainsi que Elsevier a décidé d'organiser non seulement une réunion interne à la revue, mais également, en fin de conférence, le jeudi en fin d'après midi, une réunion ouverte au public. Dr. Elaine van Ommen Kloeke, la nouvelle éditrice, a donc fait une présentation historique, puis laissé la parole à l'auditoire.

Dans cette revue, 228 articles sont publiés par année. En moyenne 65% des articles sont rejetés, pour diverses raisons dont le fait que le sujet est en dehors du *scope* de la revue ou que l'anglais est douteux. En 2012, 52% des articles soumis ont été rejetés. L'ouverture de la revue à l'internet (articles disponibles *on line*) a entrainé une augmentation des papiers rejetés. Peu d'articles proviennent d'Australie, mais beaucoup d'Inde et d'Asie. Il faut noter positivement que 10% des articles proviennent d'Afrique. Le temps d'édition est considéré comme long pour certains, mais l'éditrice place la revue dans la moyenne. Son temps de première décision est estimé à 8 semaines. Ses compétiteurs sont les revues *Crop Protection*, Jou*rnal of Economic Entomology, Pest Management Science*, *Journal of Pest Science*. Une des raisons en est le facteur d'impact, situé cependant à 1,347. Un numéro spécial (*Special Issue*) a été évoqué pour rendre compte de la conférence de Bordeaux. Cette revue me parait bien indiquée pour la publication des travaux réalisés au Bénin. Quelques articles portant sur l'usage et l'efficacité des huiles essentielles ont été publiés (fichiers pdf récupérés) qui peuvent constituer de bons modèles à suivre.

Les quelques éléments présentés ci-après proviennent du site web de la revue (http://www.elsevier.com/locate/jspr)

The *Journal of Stored Products Research* provides an international medium for the publication of both reviews and original results from laboratory and field studies on **stored products**. These include **food**, **foodstuffs** and durable items, including **materials** such as timber and museum artifacts.

Suitable subjects include:

• The biology, ecology, physiology, behavior, taxonomy, genetics and control of pests and spoilage agents
• Relevant biotechnology, pest management and decision support systems
• The physical and chemical nature of the stored product environment, including its modification
• The assessment, prevention and control of losses
• Regulatory, technological and economic subjects relevant to stored products
• The design and structure of the storage environment.

The *Journal of Stored Products Research* reflects the worldwide interest in the scientific problems of infestation in stored food and their relevance to trade and the increasing world food shortage.

For more information/suggestions/comments please contact AuthorSupport@elsevier.com

Quelques impressions personnelles - Conclusions

Avec cette conférence, c'est la troisième fois que j'assiste à une conférence donnée par un groupe de travail de la section SROP de l'OILB. Des éléments communs sont ainsi retrouvés. L'existence d'un 'noyau dur' de chercheurs qui travaillent ensemble ou se retrouvent tous les deux ans depuis de nombreuses années est un gage de bon fonctionnement de ce genre de communauté, très solidaire. Le groupe IPSP existe depuis 1992 (il y avait alors 11 participants de 7 pays). Il va changer de *convenor* cette année, Christos Athanassiou en ayant assuré l'animation depuis 2007.

En revanche, d'autres éléments de fonctionnement de ces groupes sont distincts, comme la confection du bulletin (Actes des conférences), qui sera faite après la conférence, une fois reçus fin juillet les derniers textes.

Le départ à la retraite de spécialistes de longue date est un problème qui a été soulevé dès l'introduction à la réunion. Un certain émoussement de la participation des chercheurs Européens semble se manifester après quelques années, un peu comme dans le cas des autres groupes de travail. Il est compensé par la participation accrue, et encouragée, de chercheurs non-Européens. Par ailleurs, dans le cas spécifique de cette conférence IPSP, un sponsoring non commercial a été souhaité par les organisateurs. Il n'y avait ainsi pas de stand commercial lors des pauses. Personnellement, je l'ai un peu regretté car pour des personnes extérieures au groupe, il pouvait être intéressant de connaître les méthodes et produits qu'emploie l'industrie. L'acceptation de stands implique souvent il est vrai des exposés commerciaux, de nature pas toujours scientifique.

Un excellent choix des thèmes des sessions a été fait et leur enchainement logique a permis de dégager une bonne impression d'ensemble de cette réunion. J'ai cependant regretté de ne pouvoir assister à la première partie de la session 5 sur l'emploi des insecticides. Les diaporamas ne seront pas disponibles sur un site, il faut les demander aux auteurs. J'ai demandé celui de Cornel Adler (introduction session 4). J'espère également recevoir d'un participant les références de synthèses faites et présentées lors de réunions antérieures sur l'usage des ennemis naturels.

Le thème de l'approche spatiale a souvent été évoqué lors de la réunion, mais aucun travail n'est réalisé en amont, à la source externe d'infestation des greniers et lieux de stockage. Il faudrait bien identifier les ravageurs à étudier de façon prioritaire par rapport à cette approche *landscape ecology.*

Les silos traditionnels (avec grillages) de conservation des épis de maïs en Afrique ont été montrés par C. Adler, quelques autres greniers en argile par les présentateurs du Cameroun, mais la différence entre petits producteurs (smallholders) et grands producteurs liés aux états et au thème de la sécurité alimentaire n'est pas suffisamment marquée. Or les problèmes sont quand même bien différents selon les deux situations. De ce point de vue, on peut recommander aux chercheurs africains de bien se positionner et de renforcer leurs connaissances et compétences sur ces deux plans. Avec l'augmentation de la production de céréales ou de légumineuses, la conservation de grandes quantités en silos, à des fins de maintien de prix de base correct toute l'année ou d'un stock de sécurité en cas de problème ponctuel climatique, il est certain que les états auront un besoin différent de celui des petits producteurs.

Un autre point qui n'a pas été très développé lors de cette conférence, même si certains exposés en parlaient à titre introductif, a été celui de la quantification des pertes de production quantitatives et qualitatives.

L'intérêt de ce genre de réunion reste indéniable pour les chercheurs du sud afin d'approcher les chercheurs d'un groupe européen abordant une thématique donnée et ainsi connaître les concepts, les méthodes et les principaux résultats obtenus.

Annexe 1 Informations générales sur le Groupe de travail IPSP (site OILB)

Keywords Stored products, IPM, pests, natural enemies, prevention, traps, control, food safety, urban entomology

Convenor Athanassiou C.G.

Liaison-Officer Weintraub P.

Structure The group comprises 90 participants from 26 countries.

Aim The general objectives of the group are the communication of research findings and the promotion of methods for integrated stored product protection that help to reduce the use of residue building pesticides and to avoid risks to the user as well as to the environment.

Activities The IOBC-WPRS Working Group on Integrated Protection of Stored Products meets every two years to discuss new findings regarding the following topics:

- **biology** of stored product **pests**
- **methods** of pest **prevention** during storage, transportation and handling
- pheromones, traps and other methods to **detect** stored product pests
- all aspects of **biological control**
- prevention of microflora infection and development of **mycotoxins**
- physical, chemical and other **techniques** for stored product pest **control**
- futurology: overviews and future trends on all aspects of storage pest control
- **wood-boring**, **urban**, **quarantine** and **museum pests**

Annexe 2 Résumés des travaux réalisés avec des huiles essentielles ou des extraits végétaux

29 – Effect of drying regime on the insecticidal efficacy of Cameroonian neem seed oil against *Sitophilus zeamais* Motsch. and *Callosobruchus maculatus* Fab.

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Abstract: Neem products are known for their insecticidal properties. The bio-efficacy of botanical insecticides varies across geographical locations, making it unwise to extrapolate results from one region to another. Cameroonian neem seed oils extracted from dehusked and sun-dried (DSD), undehusked and sun-dried (USD), dehusked and shade-dried (DRD) and undehusked and shade-dried (URD) kernels were used. The oils were analysed for their azadirachtin and fatty acid contents. Maize grains and cowpea seeds were coated with the neem seed oils in order to evaluate their insecticidal efficacy on *Sitophilus zeamais* and *Callosobruchus maculatus* using parameters like adult mortality, progeny production, grain damage, population increase and persistence. The DSD seeds (85.20 µg/L) were richest in azadirachtin. The major fatty acids found were palmitic acid, stearic acid, oleic acid and linoleic acid, with similar contents among the drying regimes. All neem oils caused significant and increasing mortality to *S. zeamais* and *C. maculatus* related to the contents and exposure periods. Within one day of exposure and at the highest dosage (6 ml/Kg) 83.75%, 81.25%, 77.50% and 76.45% mortality were caused to *C. maculatus* by DSD, URD, DRD and USD, respectively, while to *S. zeamais* 31.25%, 20.00%, 18.75% and 17.50% mortality were achieved, respectively.
For *C. maculatus,* maximum mortality of three times 100% and 98.69% were achieved for DSD, URD, USD (6 ml/kg, within 3 days), and DRD (6 ml/kg within 6 days), respectively. For *S. zeamais*, mortality of 100% was caused by DSD and USD (5 ml/kg) within 7 days. All neem oils inhibited the production of progeny in the weevils, reduced the percentage of grains or seeds damaged and mass losses for maize and cowpea. Oil extracted from dehusked and sun-dried kernels persisted longer on maize than on cowpea after two months of storage. Within five days of exposure, DSD oil (6 ml/kg) caused 100% and 17.5% mortality to *S. zeamais* and *C. maculatu*s, respectively. That sun-drying of neem seeds results in higher insecticidal efficacy could help farmers to dry their neem seeds easily in sun and could help avoid health risks, because sometimes during shadedrying, the seeds are attacked by fungi which may produce mycotoxins and thus be hazardous when admixed to food products. In the northern part of Cameroon where neem trees are widely available and the population is dominated by low-income farmers, neem seed oil could be adopted for the protection of maize and cowpea stocks.

30 – Insecticidal formulation based on *Ocimum gratissimum* essential oil and montmorillonite clays for maize protection

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Abstract: Bio-insecticides formulation was developed from natural Cameroonian clays using *Ocimum gratissimum* essential oil as active agent. The adsorption capacity of aroma compounds by clays was determined and improved by chemicals modifications of the clays (1). The treatment with acetyl trimethyl ammonium was particularly efficient and was explained by the increase of affinity of the adsorbate molecules toward the adsorbent.
Insecticidal tests have been conducted against the maize weevil *Sitophilus zeamais* and have shown that the insecticidal effects of formulations have been improved after clays modifications. The mortality of *S. zeamais* decreased from 100% to 95%, 87% and 0% after 7 days respectively for the essential oil adsorbed on modified clay, on unmodified clay and for formulation without clay. The formulation prepared with unmodified clay completely lost insecticidal activity after 30 days, whereas the formulation with modified clay lost about 60% of its full insecticidal potency in the same time. The remnant effect of the formulations based on essential oil varied with the adsorbent used. The insecticidal effect of *O. gratissimum* essential oil persists during 107 days when it is adsorbed on the modified montmorillonite, while adsorbed on unmodified clay, it loses all its activity at the end of 45th day. These results allow us to assert that modified clays increase the duration of the insecticidal effect of essential oils and can be used for industrial application in the production of bio-insecticides based on essential oils. The findings suggest that formulations based on essential oils and modified clays should be considered as alternatives to synthetic insecticides for use in stored product pest control.

32 – Screening of plant extracts as repellent against Stored-product insects

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Abstract: Use of phytochemicals as natural insecticides to control stored product insects is an important area of work. Studies were conducted to test the repellency of *Trichilia connaroides* (Wight & Arn) and *Clerodendron inerme* methanol extract of leaf against three stored-product insects, the lesser grain borer *Rhyzopertha dominica* (F.), the red flour beetle *Tribolium castaneum* (Herbst) and the cowpea weevil *Callosobruchus chinensis* (L.). The area preference method was used to determine the response of insects to the repellents by measuring their movement from the treated region on filter paper strip.
The average repellency of 1000, 750, 500, 250, and 100 ppm concentrate from *Trichilia connaroides* and *Clerodendron inerme* leaves totally achieved class lll (60.1-80% repellency) and class V (80.1-100% repellency) respectively after 24 hr. observation. The order of repellent activity was *Callosobruchus chinensis, Tribolium castaneum, Rhyzopertha dominica. The* concentrate of methanol-extract of *Clerodendron inerme* leaves was found to be more effective than *Trichilia connaroides* according to One Way ANOVA ($P<0.05$; & Student *t*-test). These plant extracts can be exploited as promising stored product insect control agents.

34 – The utilization of saturated atmospheres from *Syzygium aromaticum* and *Mentha pullegium* essential oils against rice fungi

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Abstract: Storage of rice is a specific ecosystem, conditioned by several factors that are difficult to control, like temperature, relative humidity, water content, oxygen availability.
This is especially true in underdeveloped countries where technological innovations such as refrigeration and controlled atmospheres represent huge investments.
Storage under deficient conditions can originate insect or fungi attack, inducing organoleptic changes (taste, flavour and appearance), nutritional losses or even mycotoxin contamination. This situation causes significant economic losses and serious health problems. Currently the use of synthetic pesticides is restrained by regulation and political pressure due to carcinogenic and teratogenic effects, and to high residual acute toxicity. It is also important to consider their long degradation times and environmental pollution issues and collateral effects on consumers. Due to such reasons, populations have become more interested on natural food conservatives. The use of essential oils from aromatic plants may be a practical alternative to the use of synthetic pesticides in preventing deterioration caused by fungi on stored rice. So in this study it was evaluated the potentiality of *Syzygium aromaticum* and *Mentha pullegium* essential oils to promote saturated atmospheres capable to protect the rice against *Aspergillus candidus*, *A. niger*, *Fusarium culmorum* and *Penicillium islandicum*.

35 – Comparative insecticidal efficacy in the Sudano-Guinean versus Sudano-Sahelian agro-ecological zones of Cameroon of FossilShield and NeemPro against *Sitophilus zeamais* on maize in storage

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Abstract: The effectiveness of the diatomaceous earth, FossilShield and the neem-based product, NeemPro in protecting stored maize against the infestation of the maize weevil, *Sitophilus zeamais*, in the laboratory was assessed in the colder and more humid Sudano-Guinean (Ngaoundere) and the hotter and drier Sudano-Sahelian (Maroua) agro-ecological zones of Cameroon. Maize grains were admixed with the two insecticides at four dosage levels for the determination of adult mortality and inhibition of progeny production. The two insecticide powders caused significant and increasing mortality to *S. zeamais*, relating to the contents and exposure periods in the two agro-ecological zones. The weevil was more susceptible to FossilShield than NeemPro, regardless of the agro-ecological zone.
Mortality caused by both insecticide powders was higher in Maroua compared to Ngaoundere. Complete mortality of *S. zeamais* was achieved by FossilShield at Maroua at the dosage level of 1.5 g/kg, but at Ngaoundere at the dosage level of 2 g/kg, 7 days after exposure. 3-d LC50 values at Maroua were 0.39 g/kg for FossilShield and 0.99 g/kg for NeemPro and at Ngaoundere 1.9 g/kg for FossilShield and 23.72 g/kg for NeemPro. At Maroua, the two tested insecticide powders completely inhibited the production of progeny in

the weevil at all the dosage levels. The highest tested contents of FossilShield (2 g/kg) and NeemPro (6 g/kg) inhibited the production of progeny by 90.50% and 87.00%, respectively, at Ngaoundere. The results indicate that the use of FossilShield and NeemPro in stored product protection in Africa would be more effective in the Sahelian regions than in the more humid zones of the continent.

38 – Study of analysis, insecticidal and antimicrobial activity of the Essential Oils of *Ferula vesceritensis* and *Thymus munbyanus*

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Abstract: This work studied the chemical composition, insecticidal activity on *Sitophilus oryzae* and antimicrobial activity of essential oil (EO) extracted from *Ferula vesceritensi*s and *Thymus munbyanus*. Analysis of the EOs was established by GC-MS. The methodology of the biocidal activity testing (dose range: 0.063-0.503 µL.cm-2) was the impregnated filter paper disk bioassay in a Petri dish or vapor phase release in a closed exposure chamber (0.503 µL.mL-1, single dose). Antimicrobial test was carried out with dose ranging from 0.3 to 20 µL.mL-1 EO in culture medium. The evaluation of the biocidal effect of oils is based on the LD50, LD90, LT50, LT90, and the values of the minimum inhibitory concentration (MIC) for antimicrobial test. The ferrule EO was composed of 45.2% of oxygenated sesquiterpenes and 28.8% other sesquiterpenes and thyme (EO) was composed of oxygenated monoterpenes with a content of 66.6%. The rod (ferrule EO) causes inhibition of microbial culture with fungal colony diameters that did not exceed 15 mm. The essential oil of thyme causes complete inhibition of growth in all other microorganisms tested at doses less than or equal to 2.5 µL.mL-1. The activity of thyme EO was more effective than the activity of ferrule EO in the treatment against rice weevil or against target microorganisms. The richness of monoterpenes in thyme known to exhibit a good antimicrobial as thymol and carvacrol, which are the major compounds of thyme EO.

39 – Effectiveness of *Laurus nobilis* and *Mentha pullegium* essential oils against *Sitophilus zeamais* Motschulsky (Coleoptera: Dryophtoridae) on stored maize

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Abstract: Laboratory studies were carried out to evaluate the effects of some essential oils from *Laurus nobilis* and *Mentha pullegium* against unsexed adult insects aged from 1 to 7 days of *Sitophilus zeamais* on stored maize.
The concentrated essential oils at different volumes of 0,5 µl, 1,5 µl, 2,5 µl, 5,0 µl and 10 µl, were poured on filter papers with 2 cm Ø each corresponding respectively to 0,039 µl/cm2, 0,119 µl/cm2, 0,199 µl/cm2, 0,398 µl/cm2 and 0,796 µl/cm2. For diluted oils, the fixed volume

of 15 µl of different concentrations of 1:150v/v, 1:100 v/v, 1:75 v/v, 1:50 v/v and 1:10 v/v either in methanol or n-hexane were used to impregnate the filter papers.
Treatments with the concentrated oils were more effective particularly those from *M. pullegium.* All the concentrations used from *M. pullegium* provided 100 % adult mortality and no progeny production was achieved. *L. nobilis* has revealed 100% adult mortality at 0,796 µl/cm2.
Regarding the treatments with diluted oils once again the oil from *M. pullegium* provided 100 % adult mortality at concentrations of 1:50 v/v and 1:10 v/v. *L. nobilis* was not effective at any of the concentrations used. There were no significant differences between the solvents used.

41 – Efficacy of *Lippia adoensis* essential oil against *Sitophilus zeamais* (Coleoptera: Curculionidae) as influenced by leaf age

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Abstract: *Lippia adoensis*' essential oils have already shown good insecticidal efficiency. Leaf composition varies with leaf age, but no report exists on the effect of leaf age on the efficacy of essential oils. We evaluated the effect of *L. adoensis'* leaf age on *Sitophilus zeamais*. After chemically analysing the essential oils, we evaluated the filter paper toxicity, the repellent and the persistence efficacy of *L. adoensis* in relation with leaves age. β-myrcene, dimethylstyrol, tagetone, piperitone oxide and delta cardinene were present in the essential oil from old leaves and absent in the other essential oil. α-terpineole and myrtenale were found in the essential oil from young leaves and absent in the other. The essential oil from young leaves killed more weevils than the one from elder leaves did but old leaves were more repellent (II ≤ Percent Repellency ≤ V) than young leaves (0 ≤ Percent Repellency ≤ I). With its persistency levels of 98.47% after 96 h, essential oil from old leaves was more persistent than that from young leaves (94.66% after 96 h). Essential oil from young leaves could be of value in stored product protection where *S. zeamais* is a problem. However essential oils from older leaves could provide more intense repellency.

42 – Refrigerating conservation of apples and in vitro testing different essential oils to control storage rots pathogens

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Abstract: The best application techniques and methods of bio-preservation of fresh fruits are the ultimate solution to control multi-resistant microorganisms and to obtain healthy and sound fruits. The present study aimed at monitoring physical-chemical quality variation of apples ('Golden delicious'), during storage in a cooled room (4°C) and at evaluating the antifungal activity of essential oils (EO) through in vitro tests with *Eugenia caryophyllata*, *Thymus vulgaris* and Citrus limon, and this on three fungi species (*Penicillium digitatum*, *Botrytis cinerea* and *Alternaria* spp.) isolated from stored apples., In-vitro tests of fungal control were carried out after chemical analyses of EO and antifungal activity were checked

during 6 months storage. The results showed after the 2nd month of storage, a loss of more than 15% dry matter loss due to fungal attacks. The dry matter decreases from (18.82 ± 0.17)% to (15.14 ± 1.755)%; a total mineral matter rate decreased of 2% was observed at the fourth week and remains stable up to the 12th week.
Flavonoid concentration decreased from 67.22 mg/100g at 4th week to 30.28 mg/100g at 12th week, according to an increase of fungal infestation by the three species. The biocontrol test with EO showed a high antifungal activity against microorganisms tested: *P. digitatum* was less sensitive than *T. vulgaris* and *E. caryophyllata* EO, with MIC = 6.25% whereas *Alternaria* spp. and *B. cinerea* MIC were assessed at 3.125%. The three fungi were moderately sensitive to *T. vulgaris* EO with MIC = 12.5%. *Eugenia caryophyllata* essential oil which has relative density (1.043), relative humidity (1.14), refraction index (1.531/ 20 °C), pH (5.9), power rotation (-0.099) and an acidity (1.04), exhibited the best MIC at 6.5% against the three fungi. This EO which can be integrated into the program of stored food bio-control as an alternative to synthetic treatments.

43 – Chemical composition, antioxidant and insecticidal activities of essential oils and ethanolic extracts from Algerian *Rosmarinus eriocalyx* Jord. & Fourr. and *Lavandula stoechas* L.

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Abstract: Essential oils (EOs) from *Rosmarinus erioclalyx* Jord. & Fourr. and *Lavandula stoechas* L. grown in Algeria were obtained by hydrodistillation with a yield of 1.6 and 0.16 ml per 100 g of fresh weight for *R. eriocalyx* and *L. stoechas,* respectively. Their analysis by CG and CG/MS shown that fenchone was the major compound of lavender essential oil (11% v/v) with camphor (6.85%), while in rosemary oil camphor was the dominant compound (39.4%) followed by α-pinene (10.4%), and the sum of p-Cymene + Limonene (11%). The ethanolic extracts of the two plants had a yield of 19.29 and 30.59% for *L stoechas* and *R. eriocalyx*, respectively. Antioxidant activity was assessed through *in vitro* tests: diphenyl-picrylhydrazyle (DPPH), radical scavenging capacity assay, and butylated hydroxytoluene (BHT), antioxidant power. The DPPH test revealed that ethanolic extracts (rosemary IC50 = 11.59 ± 0.07 mg/l and lavender IC50= 18.30 ± 0.31 mg/l) exhibited higher radical scavenging capacity than antioxidant ability (BHT test) (IC50= 28.01 ± 0.66 mg/l), and these ethanolic extracts were much more active than EOs.
Reducing power capacity correlated to BHT test results. Ethanol extracts show significantly higher reducing power activity than EOs. Sub-lethal doses, causes a significant reduction of female fecundity and of hatchability of laid eggs.

44 – Toxicity of *Newbouldia laevis* (Seem) against the Angoumois grain moth, *Sitotroga cerealella* (Olivier) in paddy rice

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Abstract: The toxicity of powders and oil extract of *Newbouldia laevis* (Seem) against *Sitotroga cerealella* (Olivier) in paddy rice was assessed at ambient temperature of 28°C (±2°C) and relative humidity of 75% (±5%). The activity of powder and oil extract of whole plant parts (leaf, stem and root) was studied at 0.0 g (control), 0.1 g, 0.2 g, 0.3 g, 0.4 g and 0.5 g, and 1, 2, 3, 4 and 5% oil concentration, respectively. All the plant powders caused high mortality of *S. cerealella* at all concentrations. All the powders significantly reduced oviposition and adult emergence of *S. cerealella* and differences were not significant. Seed damage and seed weight loss were reduced by powders. The leaf, stem bark and root bark extracts of *N. laevis* prevented adult emergence, seed damage and seed weight loss at low concentration. All extracts of *N. laevis* induced 100% mortality from the lower concentration. However, adult moth mortality increased with extract concentration and exposure time. The root bark extract was lethal within 72 h at 4% concentration; but its effect was not significantly different from that of leaf and stem bark extracts. All the extracts and powders were toxic to adult stage but the most potent was the root extract. Adult emergence was prevented by the extract of *N. laevis* and their effects were significantly different between treated and untreated control. The application of extracts did not adversely affect germination of treated seeds. In fumigant toxicity test, none of the extracts was active as a fumigant since none could cause more than 14% mortality of *S. cerealella* after 4 d exposure. There was no significant difference in the treated and untreated control. The extracts and powders from *N. laevis* are effective bioinsecticides against *S. cerealella* in stored paddy rice.

Annexe 3 Résumé d'un travail portant sur l'écologie chimique

40 – Identification of pure compounds in dried apricot and apple electrophysiologically active in *Plodia interpunctella* (Huebner)

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Abstract: Stored product insects are able to perceive a wide range of volatile organic compounds (VOCs) which orient them towards or away from the source. The principal organ of smell in insects is the antenna. The aim of this study was to use the antenna of *Plodia interpunctella* adults for the identification of electrophysiological active compounds in dried apple and apricot. Volatiles were collected using closed-loopstripping analysis (CLSA) method and analyzed by gas chromatography (GC) coupled to two detectors, a mass spectrometry (MS) and an electroantennographic detector (EAD).
The EAD consisted of *P. interpunctella* antenna placed between two electrodes from which an amplified signal is recorded by computer software. The results showed that eight VOCs from dried apple and ten from dried apricot were able to induce a response in the antenna. From dried apple, the following VOCs were identified: three alcohols (1-hexanol, 2-methyl-1-butanol and 1-pentanol), two aldehydes (hexanal and (Z)-2-heptenal), one ester (3-butyl octanoate), one terpene (3-carene) and one benzene derivative (styrene).
From dried apricot, four alcohols (1-butanol, 1-pentanol, 1-hexanol, 3-methyl-1-butanol), two esters (ethyl benzoate and 3-methyl-1-butanol acetate), one acid (acetic acid), one ketone (3-hydroxy-2-butanone), one pyrazine derivative (trimethylpyrazine) and one benzenoid compound (benzyl alcohol) were able to elicit an EAD-response in the insect.
Considering the fact that olfaction is mediated mainly by receptors on the antenna, a compound not eliciting an EAG-response can be excluded as an olfactory cue for the insect. Therefore, the aforementioned compounds will be tested for their behavioural effect (attractive or repellent) towards *P. interpunctella* adults.

Annexe 4 Résumé d'un exposé portant sur l'emploi de filet imprégné

3 - Carifend™: an alternative method to protect stored tobacco, demonstrated by laboratory trials and semi-commercial test systems under diverse climatic conditions

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Abstract: Globally there are limited tools available to protect fumigated stored tobacco from re-infestation by Cigarette beetle *Lasioderma serricorne* (F.) and Tobacco moth *Ephestia elutella* (Walker). Carifend™ is a new system designed to keep stored tobacco free of re-infestation from stored product pests. Registration approvals were obtained in accordance with local country guidelines, such as in Ecuador, France, Germany, Russia, Mexico and Brazil. The Carifend™ -System is a physical and chemical barrier which prevents adult insect immigration to tobacco protected with the Carifend™ -net. In some instances where poorly managed fumigations occur, insects which may emerge from stored tobacco are prevented from further cross-contaminating other un-infested stored tobacco. Mitigation of contact to tobacco by immigration from outside and emigration to stored tobacco is achieved by contact with α-cypermethrin coated Long Lasting Nets (or LLINs) installed over tobacco. The described method ensures no direct contact between insecticide treated nets and stored tobacco. A key benefit is that the Carifend™ -System provides continuous protection. Efficacy tests were conducted using small scale Carifend™ -Mini-Cubicles with 1m cages under both laboratory and warehouse conditions for protection of tobacco. The investigations were supported by medium scale semi-commercial trials to demonstrate the practical implementation of this technology. A cage with dimensions 4 m width x 8 m length x 6 m height (= 192 m) was employed.
Western Europe, Central Europe and Near Eastern locations were evaluated to demonstrate the potential of the Carifend™ -System to provide prolonged protection against *E. elutella* and *L. serricorne* under different climatic conditions. Results from both laboratory and field trials demonstrated unequivocally that stored tobacco was effectively protected with the Carifend™ System. Utilization of this technology in combination with good warehouse sanitation practices and initial fumigations prior to the installation of Carifend™ provided up to 100% control against adult insects of both species. The Carifend™ System represents one of the most recent developments in insecticidal-textile technologies for protection of stored goods, which reduces the dependence on costly fumigation, improves multi-functional facility use, and affords maximum protection to valuable stored goodsKeywords: Metal bin, grain, insects, molds, remote monitoring, phosphine recycling, fumigation, liquid insecticides.

Annexe 5 Résumés de trois travaux d'« excellence scientifique »

31 – (Re-)discovering cucujolides – Infochemicals for *Oryzaephilus surinamensis* and *Cephalonomia tarsalis* with potential for biological control

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Abstract: The sawtoothed grain beetle *Oryzaephilus surinamensis* L. is a serious pest on umerous stored products worldwide. Males of this species produce a set of macrolide substances, which act as aggregation pheromones when present in a combined blend.
By analysis of beetle frass a so far unknown macrolide was detected and characterized. Subsequent bioassays demonstrated that this compound arrested female, but not male beetles when presented alone. This suggests a role of the macrolide as a sexual pheromone in *O. surinamensis*. Remarkably, females of the specialized parasitic wasp *Cephalonomia tarsalis* (Ashmead) were arrested by the compound in bioassays indicating that the macrolide is used for host finding. The particular discrimination abilities of *C. tarsalis* regarding the pheromone and other beetle-associated cues shows its high potential for use in biological control.

49 – Legume entomotoxic type 1 albumins: Promising candidates for the protection of stored cereals

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Abstract: Because of the increasing concern of consumers and public policy about environmental and health issues due to the use of chemical pesticides, the search for safer molecules and control strategies is currently of great importance. Type 1b albumins are plant peptides that are naturally present in legume seeds. The entomotoxic activity of one of their representatives, PA1b (Pea Albumin 1, subunit b) against cereal weevils (*Sitophilus* sp.) was discovered 15 years ago (Delobel et al., 1998). Pa1b is an amphiphilic 37-amino acid peptide isolated from pea seeds (*Pisum sativum*), and belongs to the knottin family (http://knottin.cbs.cnrs.fr). This structural family is a group of small disulfide-rich miniproteins characterized by their stability, rigidity and resistance to proteolysis. The toxicity of PA1b via ingestion was evaluated for many insect species and the molecule proved to have a diversified host spectrum, such as cereal weevils (*Sitophilus* spp.), the mosquitoes *Culex pipiens* and *Aedes aegyptii*, and some aphid species (Gressent et al., 2007). To date, no vertebrate per os toxicity or allergenicity was reported for this peptide.
Purified from a widely available plant resource without losing its bio-activity, PA1b has great potential for use on an industrial scale and/or for use in organic farming. The potential of this peptide to limit pest damage has stimulated research on its host range, its mechanism of action, its structure, its evolutionary history and its structure-function relationships. We therefore think that in the current crop protection context, focused on biocontrol, PA1b is a promising bioactive source to control pests of stored cereals. We will show how recent results on its cellular mode of action, and its evolution in the *Fabaceae*, have even improved the potential interest of this peptide toxin family.

47 – Supercooling capacity of the endoparasitoid *Venturia canescens* (Hymenoptera: Ichneumonidae)

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Abstract: *Venturia canescens* Gravenhorst (Hymenoptera: Ichneumonidae) is a parthenogenetic koinobiont endoparasitoid which develops in the larvae of several pyralid moths and is considered as a model organism because of its rapid mass rearing and its body size. Laboratory studies were conducted, by using larvae of the Mediterranean flour moth, *Ephestia kuehniella* Zeller (Lepidoptera: Pyralidae) as a host, in order to assess the effect of age, food, availability of host and acclimation on the cold tolerance of *V.canescens* by determining the supercooling capacity. Young adults of *V. canescens* displayed significantly lower supercooling points (21.7 ± 0.6oC) compared to old ones (15.2 ± 0.2oC), irrespective of the availability of host. In general, availability of host had a moderate effect on supercooling of *V. canescens.* On the other hand, food consumption had a noticeable influence on supercooling capacity, as it enhanced significantly the supercooling point of *V. canescens*. Acclimation to low temperatures could considerably increase the supercooling capacity of *V. canescens* adults. Increase of duration of exposure to acclimation temperature resulted to lower supercooling points. Considering the overall data, adults of *V. canescens* displayed an enhanced ability to supercool, which was lower than that of its host, *E. kuenhiella*. This information would be useful in determining the potential of using *V. canescens* as a biological control agent in IPM programs, taking into consideration the adverse effects of temperature on its survival.